Transforming Healthcare Quality through Information Tehnology *

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Abstract

Information and information exchange are crucial to the delivery of care on all levels of the health care delivery system—the patient, the care team, the health care organization, and the encompassing political-economic environment. To diagnose and treat individual patients effectively, individual care providers and care teams must have access to at least three major types of clinical information—the patient's health record, the rapidly changing medical-evidence base, and provider orders guiding the process of patient care. In this frame, Information Technology can help healthcare organizations improve the quality of care that they provide, improve patient safety, improve cost-effectiveness, accelerate the translation of research findings into practice, improve care for the medically underserved, increase consumer involvement, improve accuracy and privacy, and increase their ability to monitor health nationally. Consequently, in the present article are presented some implementations of Information and Communication Technologies in the Health Care field.

Although health care sector has a long history of innovation, it currently faces major challenges. New scientific discoveries and medical technologies lead to constantly changing clinical processes. The complexity of modern medicine has increased tremendously as a result of the explosion in biomedical knowledge, rapid growth of pharmaceuticals, medical technology, and

* The authors would like thanking to Leonardo da Vinci programme who provided financial resources for the project SK/06/B/F/PP – 177443 - Vocational Education and Training for Quality of Life through Ehealthcare & Well-Being

genetics, increasing time constraints placed on health care providers, and mounting pressures to contain costs. This complexity, coupled with poorly designed healthcare delivery systems, has made it difficult for clinicians to provide safe, high-quality care on a consistent basis and has resulted in a healthcare system plagued by medical errors, inappropriate practice variation, and suboptimal care. In recent years attention has increasingly turned to the role of Information and Communication Technology as a means to improve clinical decision-making, patient safety, and overall quality of care. Over the past 30 years, research has demonstrated that Health Information Technologies can improve patient safety and quality of care.

Understanding the vision of IT for care management requires a clear definition of care management itself. On the most general level, all of healthcare can be conceptualized as a system involving two fundamentally different main processes: decision-making processes and care-delivery processes (see Figure 1).

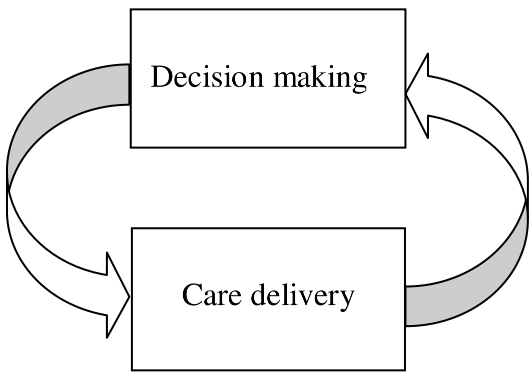

Figure 1 The main processes involving patients and clinicians

Decision-making processes involve a clinician working with a patient to determine which, if any, healthcare interventions should be pursued at a given point in the patient’s care. In this context, the phrase healthcare intervention is used broadly, encompassing everything from deciding on the components of a physical examination to deciding whether diagnostic testing or pharmaceutical or surgical treatment is needed. The output of this decision-making process is the plan of care for the patient. The care delivery process, in contrast, involves the execution of the plan of care. The results of executed interventions, in turn, affect subsequent decision making. Even the most complex clinical processes can be broken down into cycles of deciding on a plan, executing the plan, and deciding on the next plan based on the results achieved.

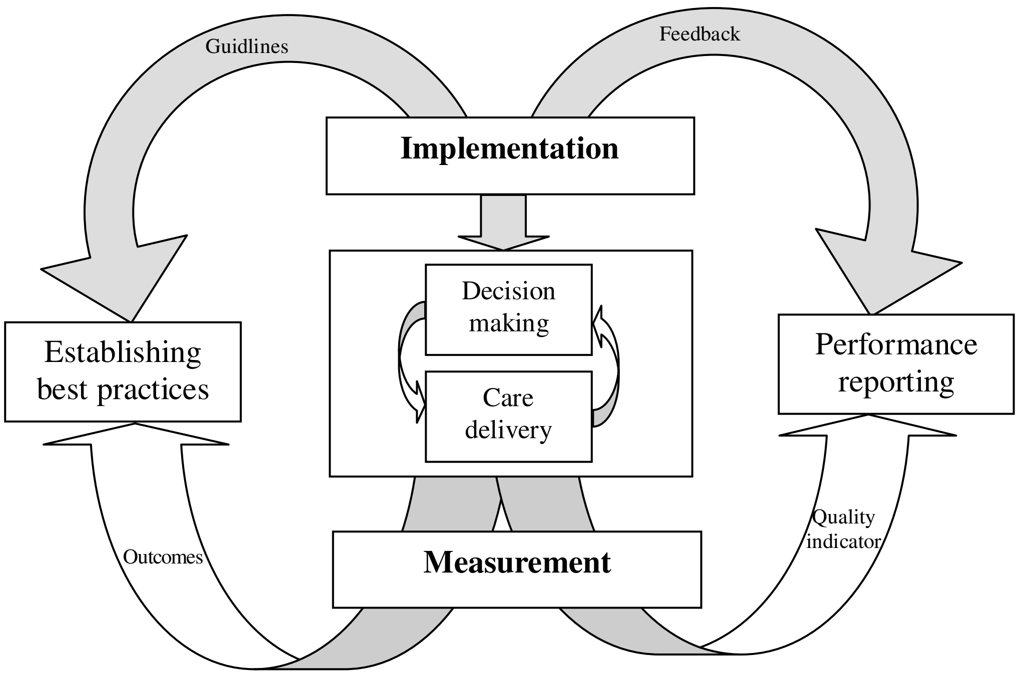

Figure 2 The care management process

Quality is defined differently for decision-making and care-delivery processes. For decision-making processes, quality means "doing the right thing"—identifying the right alternatives and choosing the right one. For care-delivery processes, quality means "doing it right"—carrying out the plan of care without making mistakes or wasting resources. As illustrated in Figure 2, decision-making and care-delivery processes interact with four important care management sub-processes to form a general framework for care management.

The first important care management sub-process is *measurement.* Given organizational commitment to measurement and the appropriate set of clinical IT capabilities, data to support outcomes measurement and quality indicators can be collected as part of routine care-delivery processes. The data needed for measurement include characteristics of the patient, his or her risk factors, the medical interventions offered, and both immediate and long term health and economic outcomes experienced by the population, including functional status, quality of life, satisfaction, and costs.

Measurements, in turn, support two other important care management sub-processes: *establishing best practices* and *performance reporting*. Best practices include practice guidelines, protocols, care maps, appropriateness criteria, credentialing requirements, and other forms of practice policies. The process of establishing best practices involves clinical policy analysis, which is supported by the scientific literature and by available outcomes information. In addition, when these two sources of information are incomplete (as they often are), expert opinion is utilized.

Recognizing that practice guidelines and other types of practice policies are meaningless unless they are used to affect clinician and patient decision making, the final important care management sub-process is *implementation*.

Implementation involves the use of a wide variety of methods, including clinician and patient education; various decision aids such as reminders, alerts, and prompts; and incremental improvements or more extensive reengineering of care delivery processes. A particularly important method of supporting implementation is the use of feedback of performance reporting data to clinicians.

In this context, a great variety of practical implementations of health information systems have been proposed. They differ in origin, target needs addressed, approaches, core technologies and architectures. In the following we present some implementations found in the literature: Electronic Health Records Systems, Clinical Decision Support Systems, Electronic prescribing Systems.

Electronic Health Records Systems

The Electronic Health Record (EHR) is a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data and radiology reports. The EHR automates and streamlines the clinician's workflow. The EHR has the ability to generate a complete record of a clinical patient encounter - as well as supporting other care-related activities directly or indirectly via interface - including evidence-based decision support, quality management, and outcomes reporting.

Each time an individual visits a health care provider, data are generated. Figure 3 identifies some of the sources of data for an EHR.

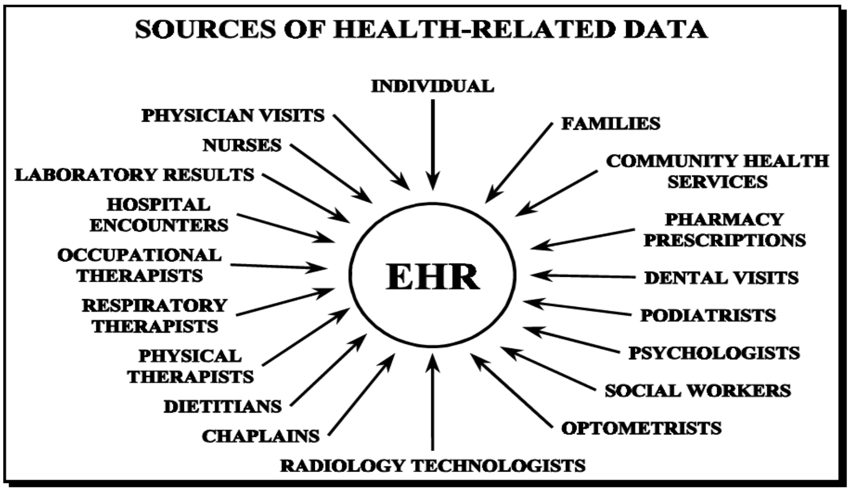

Figure 3 Sources of data for an EHR
(adapted from Institute of Medicine (IOM))

Once the data have been collected, they are placed in many repositories or databases that are part of many health systems. From these systems, specific pieces of a patient's information are combined to create a core data set that is made available to other systems. The core data set includes health and administrative data. Its format must be agreed to by all stakeholders. The systems providing the information are referred to as feeder systems (e.g. laboratory systems). Other systems that use the data are called support systems (e.g. billing systems). To provide a comprehensive EHR, these systems must be linked, thereby allowing access to patient data regardless of their physical location. This introduces another level of complexity—system interoperability. The following diagram depicts the relationship of these systems.

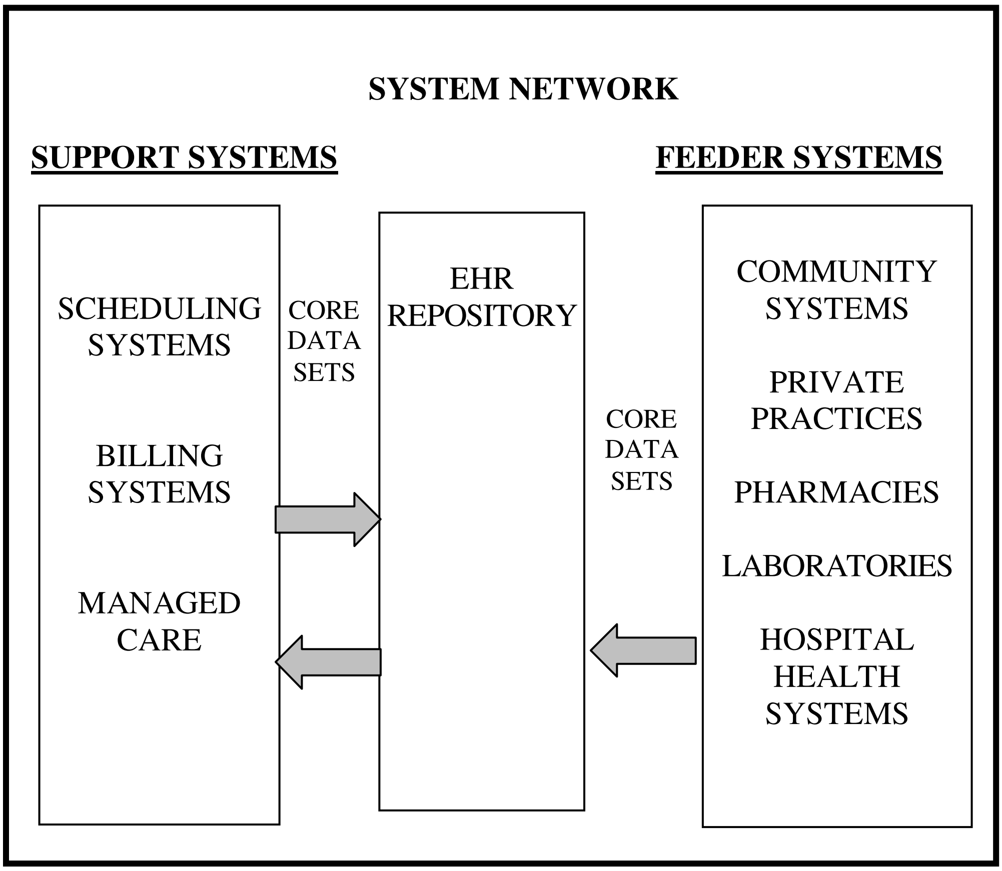

Figure 4 System network interoperability

In the following is presented a simplified conceptual view of the creation, uses and considerations affecting an EHR. As a simplified conceptual model, it does not show the complexities (e.g. range of health care professionals, volumes of data or the implications of legacy systems) inherent in building a technology infrastructure. The diagram of the conceptual overview is divided into two major sections: the left side depicts the components involved in the *creation* of an EHR, and the right side identifies the users and tools required to *access* the Network.

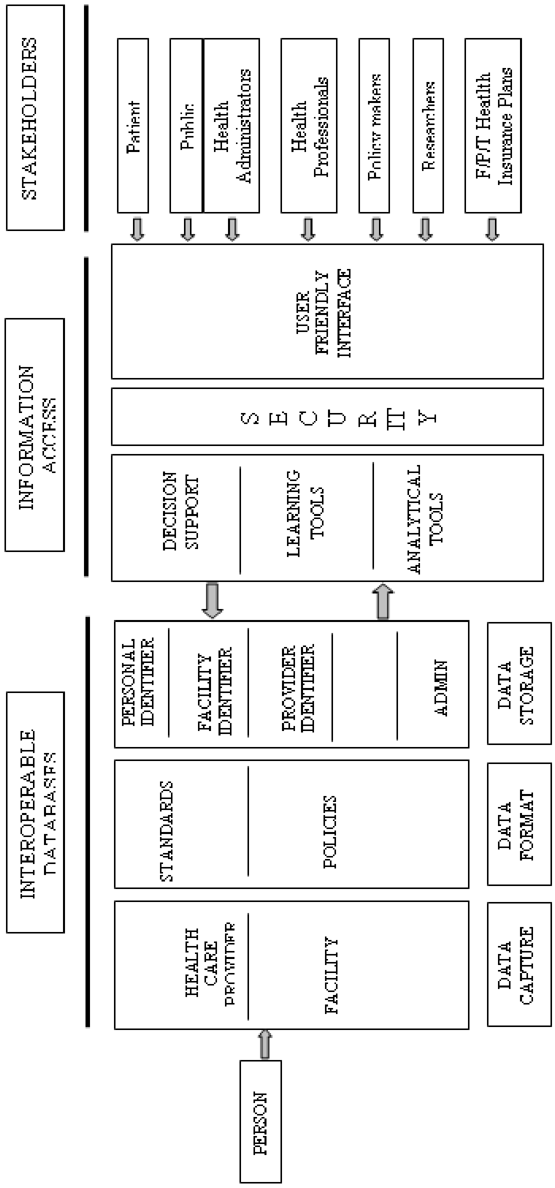

Figure 5 Electronic Health Record System / Conceptual overview

The creation of the Health Network (left side) involves the interaction of a person with a health care provider or health facility. The data are captured, subjected to standards and policies, and will then be stored with identifiers (person, facility and provider) as well as health and administrative data in interoperable databases.

The right side of the Health Network illustrates how various stakeholders access the data stored in the databases by using user-friendly interfaces, security levels (to protect privacy and confidentiality) and various tools.

In other words, once the requirements of an EHR are identified, an infostructure is required within which the EHR system will function. As previously stated, the EHR contains all health information generated by all the health care providers an individual interacts with over that person's lifetime. Each interaction will result in an Incident Record that will reside in a system. When these systems become interoperable, the building of the health infrastructure begins.

Clinical Decision Support Systems (CDSS)

Clinical decision support systems (CDSSs) form a significant part of the field of clinical knowledge management technologies through their capacity to support the clinical process and use of knowledge, from diagnosis and investigation through treatment and long-term care.

Clinical DSSs are typically designed to integrate a medical knowledge base, patient data and an inference engine to generate case specific advice.

Four key functions of electronic clinical decision support systems are outlined in [Perreault & Metzger]:

- Administrative: Supporting clinical coding and documentation, authorization of procedures, and referrals.

- Managing clinical complexity and details: Keeping patients on research and chemotherapy protocols; tracking orders, referrals follow-up, and preventive care.
- Cost control: Monitoring medication orders; avoiding duplicate or unnecessary tests.
- Decision support: Supporting clinical diagnosis and treatment plan processes; and promoting use of best practices, condition-specific guidelines, and population-based management.

The basic components of a CDSS include a dynamic (medical) knowledge base and an inferencing mechanism (usually a set of rules derived from the experts and evidence-based medicine) and implemented through medical logic modules based on a language such as Arden syntax (a grammar for describing medical conditions and recommendations, used in Medical algorithms). It could be based on Expert systems or artificial neural networks or both (connectionist expert systems).

Knowledge-based systems are the commonest type of CDSS technology in routine clinical use. Also known as expert systems, they contain clinical knowledge, usually about a very specifically defined task, and are able to reason with data from individual patients to come up with reasoned conclusions. Although there are many variations, the knowledge within an expert system is typically represented in the form of a set of rules.

There are many different types of clinical task to which expert systems can be applied.

- *Alerts and reminders*. In real-time situations, an expert system attached to a patient monitoring device like an ECG or pulse oximeter can warn of changes in a patient's condition. In less acute circumstances, it might scan laboratory test results, drug or test order, or the EMR and then send reminders or warnings, either via immediate on-screen feedback or through a messaging system like e-mail. Reminder systems are used to notify clinicians of important tasks that need to be done before an event occurs. For example, an outpatient clinic reminder system may generate a list of immunizations that each patient on the daily schedule requires [Coiera].

- *Diagnostic assistance*. When a patient's case is complex, rare or the person making the diagnosis is simply inexperienced, an expert system can help in the formulation of likely diagnoses based on patient data presented to it, and the systems understanding of illness, stored in its knowledge base. Diagnostic assistance is often needed with complex data, such as the ECG, where most clinicians can make straightforward diagnoses, but may miss rare presentations of common illnesses like myocardial infarction, or may struggle with formulating diagnoses, which typically require specialised expertise.
- *Therapy critiquing and planning*. Critiquing systems can look for inconsistencies, errors and omissions in an existing treatment plan, but do not assist in the generation of the plan. Critiquing systems can applied to physician order entry. For example, on entering an order for a blood transfusion a clinician may receive a message stating that the patient's haemoglobin level is above the transfusion threshold, and the clinician must justify the order by stating an indication, such as active bleeding [Coiera]. Planning systems on the other hand have more knowledge about the structure of treatment protocols and can be used to formulate a treatment based upon a data on patient's specific condition from the EMR and accepted treatment guidelines.
- *Prescribing decision support systems.* One of the commonest clinical tasks is the prescription of medications, and PDSS can assist by checking for drug-drug interactions, dosage errors, and if connected to an EMR, for other prescribing contraindications such as allergy. PDSS are usually well received because they support a pre-existing routine task, and as well as improving the

quality of the clinical decision, usually offer other benefits like automated script generation and sometimes electronic transmission of the script to a pharmacy.

- *Information retrieval*. Finding evidence in support of clinical cases is still difficult on the Web, and intelligent information retrieval systems can assist in formulating appropriately specific and accurate clinical questions, they can act as information filters, by reducing the number of documents found in response to a query to a Web search engine, and they can assist in identifying the most appropriate sources of evidence appropriate to a clinical question. More complex software 'agents' can be sent to search for and retrieve information to answer clinical questions, for example on the Internet. The agent may contain knowledge about its user's preferences and needs, and may also have some clinical knowledge to assist it in assessing the importance and utility of what it finds.
- *Image recognition and interpretation*. Many clinical images can now be automatically interpreted, from plane X-rays through to more complex images like angiograms, CT and MRI scans. This is of value in mass-screenings, for example, when the system can flag potentially abnormal images for detailed human attention.

There are numerous reasons why more CDSS are not in routine use. Some require the existence of an electronic patient record system to supply their data, and most institutions and practices do not yet have all their working data available electronically. Others suffer from poor human interface design and so do not get used even if they are of benefit.

Much of the initial reluctance to use CDSS simply arose because they did not fit naturally into the process of care, and as a result using them required additional effort from already busy individuals. It is also true, but perhaps dangerous, to ascribe some of the reluctance to use early systems upon the technophobia or computer illiteracy of healthcare workers. If a system is perceived by those using it to be beneficial, then it will be used. If not, independent of its true value, it will probably be rejected. Happily, there are today very many systems that have made it into clinical use. Many of these are small, but nevertheless make positive contributions to care. Others, like prescribing decision support systems, are in widespread use and for many clinicians form a routine part of their everyday practice.

Electronic prescribing (eRx)

Electronic prescribing, often abbreviated to e-prescribing or eRx, is a system that enables prescribing clinicians to deliver prescriptions via computer immediately from the point of care directly to the patient's pharmacy of choice. In addition to this efficient and accurate prescription delivery function, e-prescribing improves patient safety through warnings to the prescribing clinician about adverse drug interactions, allergies, and previous medication history. E-prescribing systems can also provide information on insurance eligibility status, prescription fill status notification, and prescription renewal capability, all of which can save time and money for all parties involved in the transaction.

Electronic prescribing that integrate patient data and drug information can offer the following benefits:

- "Computers can maintain accurate, unbiased, and up-to-date drug databases, which constitute essential tools as the number of approved medications continues to increase.
- Proscribes can receive on-screen prompts for drug-specific dosage information, with reminders to ensure that look-alikes and sound-alikes are not confused.

- Vital patient-specific information, such as overdose warnings, drug interactions, and allergy alerts, can be presented in the course of prescribing, so that potential adverse drug events that would otherwise go unrecognized can easily be avoided.
- Computers can reduce, even eliminate, the margin for error by flagging pre-existing medical conditions or concurrent medications that would preclude use of certain drugs in individual patients.
- Electronic prescribing can expedite refill requests, once patients are entered into the system.
- Computers can facilitate data exchange to enhance teamwork between clinicians and professionals who represent other parts of the medication management system, such as pharmacists in retail, hospital, and online environments; pharmacy benefit managers; and health plans.
- Computers can enable practitioners to stay abreast of changes in formularies and insurance coverage.
- The use of computers can reduce healthcare costs through time and efficiency savings and by encouraging prescribers to consider lower-cost drug options."

But is it possible that electronic prescribing systems, could — potentially — introduce a number of errors. The following tables are presented some problems appearing in the use of electronic prescribing systems.

Problems That Electronic Prescribing Can Solve . . . and Create

Table 1

Problems with Traditional Prescribing	Corrective Features of EMR-Based Electronic Prescribing Systems	Problems Electronic Prescribing May Introduce
Diagnosis and Prescribing Wrong chart or incomplete/illegible history in chart (i.e., missing allergies, other meds, other conditions).	Patient identity checks. Complete history at hand. Safety alerts triggered Complete current medications list /medication history Instant access to MEDLINE, PDR.	Wrong patient name may be selected from list; patient ID info may not be displayed on each new screen. Wrong diagnosis may be selected. Alerts may be inactivated or ignored. History or alerts may not be up-to-date or records of other prescribers may not be accessible.
Lack of information on Rx coverage.	EMR includes coverage info/formulary.	Coverage or formulary may not be updated.
Rare diagnosis or diagnosis for which off-label Rx being tried.	System can recommend drugs.	May be unable to Rx off-label. If diagnosis entry required and inaccurate diagnosis entered, could affect future care.

Problems with Traditional Prescribing	Corrective Features of EMR-Based Electronic Prescribing Systems	Problems Electronic Prescribing May Introduce
Writing and Transmitting Incorrect dose calculated and written.	Menus decrease wrong-dose errors.	Some menu designs can increase wrong dose choices.
Rx or dose misread by office staff.	Electronic record of prescription accessible to pharmacies or transmissible via email.	Some office and pharmacy computer systems are incompatible. Delayed transmission of prescription.
Dispensing Patient must go to pharmacy to obtain medication.	May support automated in-office dispensing.	In-office dispensary may detect fewer prescribing errors than a pharmacist would.
Pharmacist or tech may misread medication or dose.	Electronic record of prescription is sent.	Pharmacist may check less carefully for errors.
Providing Patient Education Prescriber may provide no information about how drug should work, possible side-effects, correct route and timing of administration, resulting in administration errors.	Can produce educational materials; may facilitate MD, RN, and pharmacist collaboration. Can help schedule and track administration.	Poorly designed materials could result in inconsistent instructions, misunderstandings, which could increase errors.

Problems with Traditional Prescribing	Corrective Features of EMR-Based Electronic Prescribing Systems	Problems Electronic Prescribing May Introduce
Monitoring and Follow-Up Patient may fail to fill or refill Rx.	Systems could notify prescribers when patients fail to fill Rx.	
Patient may not think to notify prescriber of adverse reactions.	Systems could produce questionnaires to track adverse reactions.	
Prescriber may not schedule or notify patient of required or recommended monitoring tests.	Systems could automatically trigger proscribe reminder or patient notification.	Time-consuming, but could save time in the long run.

The key to success in reducing medication errors is to have all relevant databases pertaining to patients available to practitioners at the point of care. Such a system should interact with the following databases:

- Patient-specific data: allergies, International Classification of Diseases codes, medication history, etc.;
- Patient's laboratory work;
- Insurance companies and third-party payers;
- Current Procedural Terminology codes and diagnosis;
- Drug information and clinical guidelines;
- The patient's electronic medical records;
- Billing functions ;
- Patient scheduling system.

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